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A Study of Parton Distribution Functions with the Use of Photon + Jet Event Kinematics in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV

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ABSTRACT

We have measured the leading jet pseudorapidity distribution in photon + jet events selected from the inclusive direct photon event sample. The data are from $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV recorded with CDF in the 1992-1993 run. This measurement has been used to study the behavior of current parton distribution sets in selected kinematic regions. The parton distribution sets CTEQ2M and MRSD0 are currently favored by this measurement.

1. Motivation

Prompt photon production is a direct probe of the gluon distribution through the leading order QCD Compton process, $gq \rightarrow \gamma q$. The behavior of the parton distributions can be studied in selected kinematic regions by measuring the pseudorapidity distribution of the highest E_t, or leading jet.

In lowest order QCD, the incident parton momentum fractions, x_a and x_b, can be calculated on an event by event basis from the following equation.

$$x_a = \frac{P_t}{\sqrt{s}}(e^{\eta_\gamma} + e^{\eta_{jet}}) \text{ and } x_b = \frac{P_t}{\sqrt{s}}(e^{-\eta_\gamma} + e^{-\eta_{jet}})$$

Here, P_t is the transverse momentum of the direct photon, η_γ is the eta coordinate of the photon and η_{jet} is the eta coordinate of the jet. A measurement of the η_{jet} distribution probes variations in the x range of the two incident partons.

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2. Event Selection

This analysis is a direct extension of the prompt photon cross section measurement.[1] Events were selected using the standard inclusive photon selection cuts from the 16.3 pb^{-1} of data with photon 16 $GeV/c < P_t < 40$ GeV/c. The removal of background resulting from neutral meson decay has been described previously.[1]

Some fraction of the data are photon + 2 jet events resulting from a hard gluon emission in the initial or final state. To select photon + 1 jet events, the photon and jet were required to be back-to-back in the azimuthal coordinate ϕ within 30°, $150^o < \Delta\phi < 210^o$. This requirement was satisfied by 74% of the data and by 98% of monte carlo generated photon + 1 jet events with no underlying event simulation.

3. The Leading Jet Pseudorapidity Distribution

The leading jet pseudorapidity distribution is shown in fig. 1a. The theory is a NLO calculation[2] using CTEQ2M[3] parton distributions. In fig. 1b the data have been normalized to the theory using the CTEQ2M parton distribution functions. In addition all data points have been divided by the value in the first bin. Other theory curves are shown which use the CTEQ2MF,[3] CTEQ2ML[3] and the MRSD0 [4] parton distributions. Figure 1b shows differences between parton distribution functions in the high η_{jet} region. CTEQ2M and MRSD0 are currently favored by this measurement. The high η_{jet} region of the leading jet pseudorapidity distribution is populated by events with the greatest difference between the incident parton fractional momenta, x_a and x_b. As the leading jet pseudorapidity increases, the momentum of the most energetic of the two incident partons in each event increases from 0.03 to 0.4 while that of the least energetic parton decreases from 0.02 to 0.01. The range of x available in this measurement extends from 0.01 to 0.4.

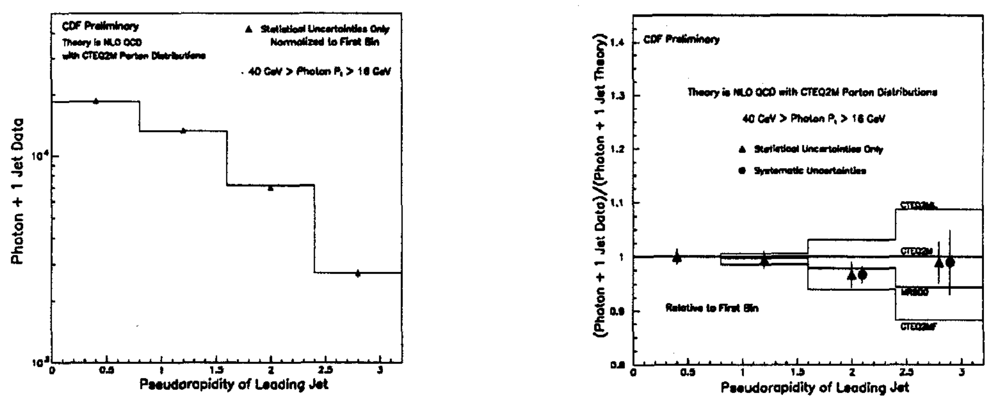

Fig. 1. **a)** The leading jet pseudorapidity distribution. **b)** The leading jet pseudorapidity distribution normalized to CTEQ2M theory and divided by the value of the first bin.

As the leading jet pseudorapidity increases the NLO theory based on CTEQ2MF parton distributions decreases by about 14% relative to that based on CTEQ2M parton distributions. Leading order QCD predicts that roughly 40% of this effect is due to the difference in the gluon distributions at high x and another 40% is due to the difference in the quark distributions at high x. About 20% is due to the combined differences between the low x gluon and quark distributions.

4. The Simulation of Events used for Corrections to the Measurement

Simulated events were used to study the jet eta resolution of the calorimeter and the extent to which misidentification of the leading jet occurred. The simulated events were generated with Papageno.[5] The underlying event and the hadronization of the generated partons was modeled by a standard CDF algorithm which was tuned on the data of the 1987 run. Another standard CDF routine was used to perform the CDF detector simulation.

5. Corrections for Detector Resolution Effects

The monte carlo generated events were used to estimate the jet eta resolution in each η_{jet} region. A combination of 10% photon + 2 jet events and 90% photon + 1 jet events both with underlying event was used for this procedure. The fractional number of times that the eta coordinate of the parton and that of the corresponding jet were in different bins was determined for each bin in the measurement and a bin-by-bin correction was performed. This effect was $\approx$ 10% between neighboring bins.

Using this same set of generated events it was determined that less than 4% of the jets were too spatially broad to be recognized by the clustering algorithm. The resultant lost jet was replaced by an upward fluctuation in the underlying event energy $\approx$ 90% of the time. A bin-by-bin replacement of the less than 1% of events for which no jet was recorded was performed. In a small percentage of events the leading jet was misidentified when the leading jet E_t fluctuated below that of the second jet due to the E_t resolution of the calorimeter.

6. Systematic Uncertainty

The systematic uncertainty quoted in fig. 1b results primarily from the uncertainty associated with the model of the underlying event used to perform the η_{jet} resolution unsmearing correction discussed above. The uncertainty due to the photon + 2 jet component of the data is at most half of the uncertainty introduced by the modeling of the underlying event. The systematic uncertainty in the shape of the distribution due to the statistical background subtraction is $\approx$ 2% in each bin of the measurement.

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